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Management of locusts and grasshoppers in China

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Abstract

Locusts and grasshoppers are major economic pests in China and are controlled by a strategy of preventive management where about 1.5 million ha are treated each year. The preventive management system aims to keep locusts and grasshoppers at lower densities, so that the dense swarms seen in the past are no longer common and crop and pasture damage minimized. There is substantial cultural control, including conservation of natural enemies and reducing the area of favorable habitats through habitat modification. Even with substantial cultural control, locust and grasshopper infestations are still widespread, with 127 field stations having more than 2000 technicians involved in monitoring and control. These officers monitor and treat locust and grasshopper infestations and the data collected are integrated into a national computer-based platform. These data are analyzed and news bulletins are issued on where and when the densest infestations are likely to be so that extra resources can be provided when needed as part of coordinating an effective locust and grasshopper management program. In the past, treatments were by chemical pesticides, but in recent years there has been an increasing use of bio pesticides: namely, the naturally occurring fungus *Metarhizium acridum* and the microsporidian *Paranosema locustae*. While such products were used in only 5% of treatments during 2004, their use has increased to over 30% in recent years, which amounts to over 100,000 ha per year sprayed. These applications of bio pesticides against locusts and grasshoppers are more than all of the rest of the world combined.

Key words

biological control, habitat modification, history, information platform

The long history of the locust and grasshopper problem in China

Locusts and grasshoppers are serious pests to crops in many areas of the world and can cause serious economic loss (Wright 1986, Brader et al. 2006, Millist and Abdalla 2011, Latchininsky 2013). In China, locust plagues have had a 3000-year history (Fig. 1) (Zhou 1990), with more than 800 plagues recorded since 707 BC. Since ancient times, locust plagues, along with floods and droughts, have been considered one of the three biggest natural disasters. According to Ma et al. (1965), who studied detailed data from the 11th to 19th centuries, plagues occurred about every 9–11 years and were present in nearly half of years in most centuries. The frequency of damaging plagues led ancient Emperors and their governments to mandate treatment programs: full time locust control officers were appointed during the Tang Dynasty in the eighth century (Wang et al. 2003). Laws were also passed during the 11th, 12th and 15th centuries that required local governors to conduct locust control, which included paying people to catch locusts and then bury them in pits.

There were many ancient poems describing locust outbreaks and their control such as one by Juyi Bai during the Tang dynasty:

"Locust outbreaks distributed widely in the center,
Eating like silkworms and flying like rain.
Green crop shoots disappear,
Only black soil left for thousands of miles,
Governors worried about yield,
Demand that people catch locusts day and night."

The current locust and grasshopper problem

Migratory locusts, *Locusta migratoria* (Linnaeus, 1758) are serious pests in a number of regions in China (Fig. 2). The taxonomic relationships between migratory locusts have recently been revised such that those in the north are *Locusta migratoria migratoria* (Linneaus, 1758) and those in the south are *L. m. migratorioides* (Fairmaire & L.J. Reiche, 1849) (Ma et al. 2012). The northern infestations consist of those in the northwest, which are contiguous with those of neighboring countries and their management at times requires cooperative efforts with those countries, and those in eastern China, which are often the most important. In the past the northern infestations sometimes were continuous but in recent years preventive management programs have limited the size of these infestations such that the northwest and east infestations are now managed quite separately. In the south are also two separate infestations: on and near Hainan Island and near the Tibetan plateau. Overall, migratory locusts commonly infest about 290 counties in 17 provinces, covering between 1.5 to 3 million ha

Fig. 1. Chinese character representing locusts on an Oracle bone inscription in a 3000-year-old Shang Dynasty tomb. The character within the red circle means locust in ancient Chinese.

Table 1. Area infested by economically important locusts and grasshoppers.

	Locusts and grasshoppers	Distribution	Range in area infested/year (millions of ha)
Locusts	*Locusta migratoria*	17 provinces, ~290 counties	1.5–3.0
Grasshoppers in agricultural lands	900 species in total, 60 spp. economically important	18 provinces, ~500 counties	4.7–7.0
Grasshoppers in grasslands	800 species in total, 50 spp. economically important	13 provinces, ~300 counties	12.0–18.0
Total			18.2–28.0

each year (Table 1). There are also economically important grasshoppers in many areas of China (Fig. 3), and each year they infest up to 7 million ha of crops (which is about 10% of the total crop area) and 18 million ha of grasslands (which is about 5% of the total area of grassland) (Table 1). Clearly, locust and grasshopper infestations are widespread and significant treatment programs are conducted to limit the damage these pests can cause to grasslands and crops. During major outbreaks between 1999-2004, 2-3 million ha were treated each year, though in recent years treatments have averaged about 1.5 million ha.

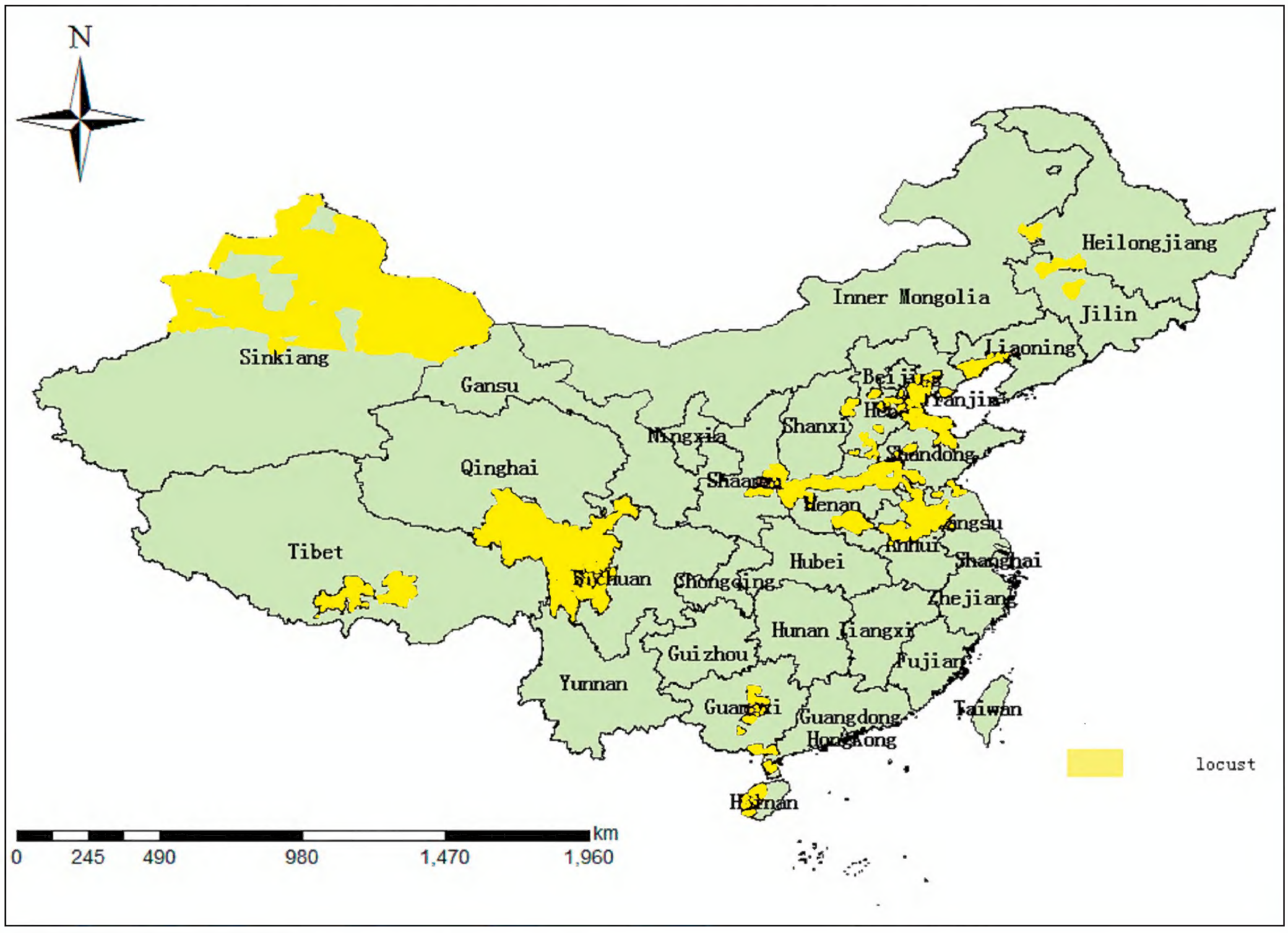

Fig. 2. Regions where migratory locusts are common in China.

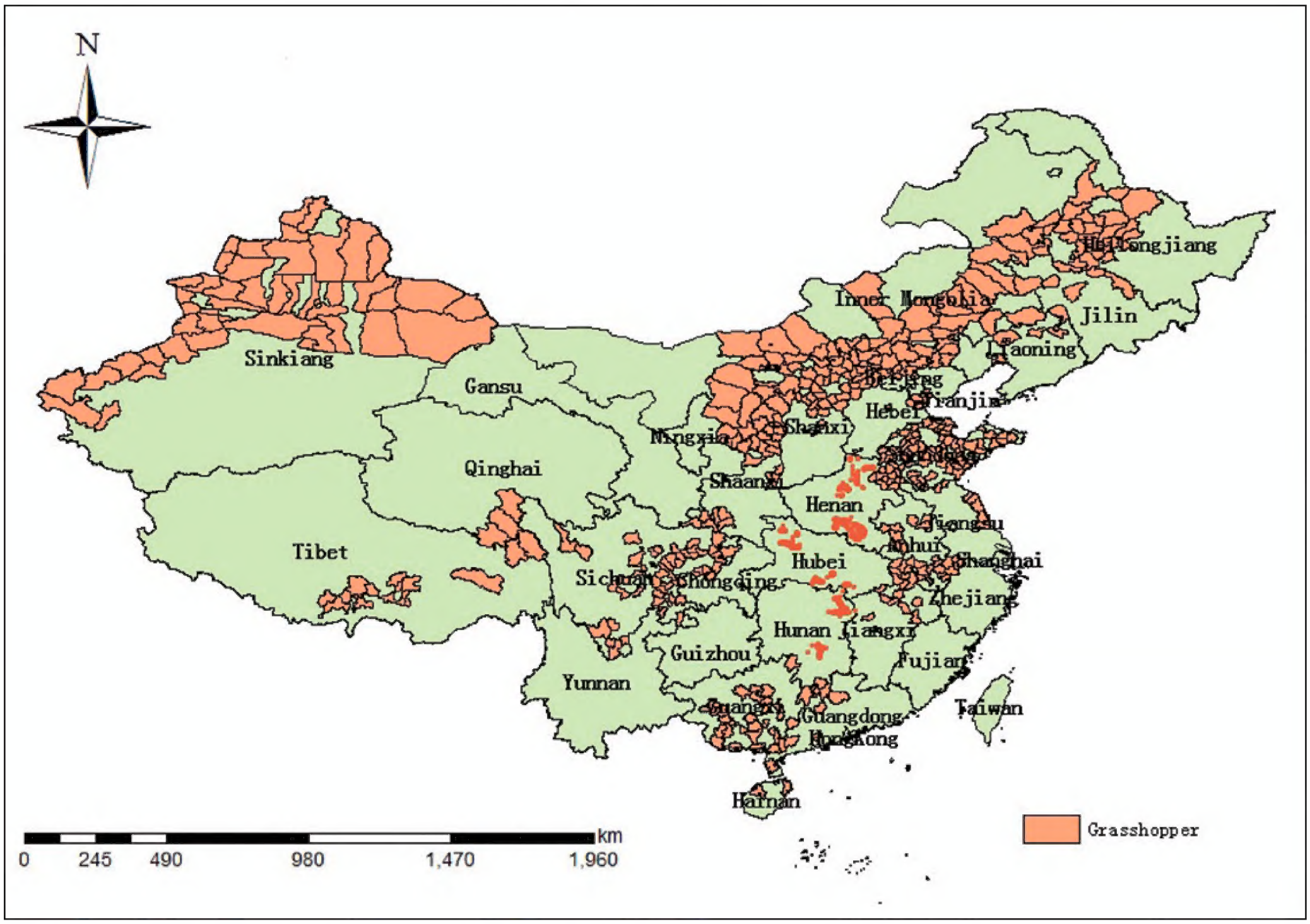

Fig. 3. Regions where pest grasshoppers are common in China.

At times grasshoppers like *Oedaleus asiaticus* Bey-Bienko, 1941 migrate into cities where they are attracted to light at night, and during the years 2002-2009 there were many reports of them falling like rain, covering streets and gardens. A number of grasshopper species are a major problem in the north and west of China and, along with the Asian migratory locust, often invade China from neighboring countries, particularly Mongolia and Kazakhstan. The trans-boundary movement of these pests has led to an international cooperative treatment program between the Chinese and Kazakh governments. Locusts and grasshoppers in these northern areas have one generation per year, though some species have two generations per year further south and migratory locusts have three or even four generations per year on Hainan Island in the far south.

Monitoring for locust and grasshopper populations is quite labor intensive and involves digging up egg beds to monitor egg development as well as regular surveys to determine locust densities and distribution. Treatment programs often involve spraying using ground equipment, and aircraft are used to treat larger infestations, requiring staff to mark the boundaries of spray targets. Efforts are being made to identify inefficiencies in all of the processes involved in the monitoring and treatment of locusts and grasshoppers as part of an improved management program and such improvements require updated training such that technicians are well-trained in the latest techniques.

The preventive management strategy for locust and grasshopper control

The current management strategy for locust and grasshopper control is *preventive* in that the aim is to keep locusts and grasshoppers at lower densities, so that migration is much reduced and crop and pasture damage minimized. The dense swarms of the migratory locust are much less common than in the past and when such swarms do form, they are quickly treated so that there have not been swarms in plague proportions for many years. There has been a great deal of recent research on this locust and this has led to substantial modernizing of management programs (Zhang 2011). Migratory locust breeding has been shown to be common in the large flood prone areas near rivers and lakes with locust numbers higher when precipitation is less (Tian et al. 2011) which, in China, is often associated with El Niño events (Zhang and Li 1999). Stige et al. (2007) showed that during dry periods following floods, large areas of green vegetation are exposed providing substantial areas suitable for locust breeding. The association of migratory locusts with the reeds in flood prone areas led Ma et al. (1965) to suggest that flood mitigation and habitat modification could reduce these favored areas substantially. Many of the rivers have been dammed to control floods, reducing the size of flooded areas (Chen 1979, Zhu 2004). In many areas, the reeds favored by locusts have been replaced with non-host plants such as *Rob-*

inia pseudoacacia L. (false acacia) or *Ziziphus jujuba* Miller (Chinese date) or non-host crops like alfalfa or cotton. Studies have shown that in areas where non-host trees have been planted, locust densities have declined by more than 90%. The areas favorable for locust breeding are now much reduced and have been mapped (Zhu 1999) so that they can be extensively monitored for locust activity. For grasshoppers in pastures, conservation of natural enemies is important: in northwest of China, rosy starlings (*Pastor roseus* L.) are not only conserved, but bird nests are also constructed, to provide nesting places for the birds on farms.

In the past, almost all treatments were by chemical pesticides but in recent years, non-chemical control forms an increasingly important part of locust and grasshopper management in China (Zhu et al. 2013). There has been substantial use of the naturally occurring fungus *Metarhizium acridum* (Driver and Milner) and the microsporidian *Paranosema locustae* (Canning) (formerly, *Nosema locustae*). While such products were used in only 5% of treatments during 2004, their use has increased to over 30% in recent years, which amounts to more than 100,000 ha per year sprayed with these products. These applications of bio pesticides against locusts and grasshoppers are more than all of the rest of the world combined. The aim is to have 60% of treatments with non-chemical control by 2020. Local production of these bio pesticides has meant their price is almost the same as that of chemical pesticides and while mortality is slower than with chemicals, a high level of mortality can be obtained both with *Metarhizium* (Zhang and Hunter 2005, Ding and Zhang 2009, Zhang 2011) and with *Paranosema* (Zhang et al. 1995, Gong et al. 2003, Fu et al. 2010).

With *Paranosema*, Zhou and Zhang (2009) conducted laboratory experiments to increase the virulence of local and introduced strains by choosing spores from locusts that died most quickly and infecting the subsequent generation of locusts. The LD_{50}'s of three different strains declined by 26%, 56% and 76% respectively after three generations of selection. And the two bio pesticides commonly used complement each other: *M. acridum* causes a high (>80%) mortality more quickly (in 10–14 days), while *P. locustae* generally leads to a lower initial mortality (60-70%) but horizontal transmission between individuals and vertical transmission between generations means the latter continues to cause mortality for many weeks and months and even in subsequent years (Zhang et al. 1995, Gong et al. 2003, Zhang and Yan 2008). The major advantages of using bio pesticides, which include specificity to locusts and grasshoppers, preservation of natural enemies (Zhang and Hunter 2005), as well as avoiding chemical residues both in agricultural products and in environmentally sensitive areas such as near water, mean that the credibility of having bio pesticides as part of management programs is being recognized (Hunter 2010).

Integration of data into a preventive management platform

Data collected on locusts and grasshoppers are integrated into a computer-based platform that analyses data and issues news bulletins on where and when the densest locust and grasshopper infestations are likely to be. Within the platform, areas favored by locusts and grasshoppers have been digitally mapped. To these maps are added the survey data collected by field officers: the GPS coordinates of locations having locusts or grasshoppers are recorded by mobile devices and the data are then transferred to the computer-based platform. The location of areas treated are recorded either by GPS for ground treatments or DGPS (Differential Global Positioning System) for treatments by aircraft and these are also sent. The management platform analyses these data as part of providing an effective organization for locust and grasshopper control at both national and local levels (Li et al. 2014).

The preventive management platform is part of a well-organized system for locust and grasshopper management. There are now 127 field stations with more than 2000 technicians involved in locust and grasshopper monitoring and control. The central and provincial governments coordinate the efforts of these technicians and ensure that they are well trained and that the field stations are well equipped with pesticides, application equipment and staff. But a critical part of the management system is the central authority's use of the preventive management platform to allow recognition of areas with the densest infestations. Extra resources can then be provided when needed as part of ensuring the successful implementation of the locust and grasshopper management program.

Future prospects

Research areas that show promise in locust and grasshopper management include investigations of other bio control alternatives including the fungus *Aspergillus*, which has been shown to have high virulence against locusts, causing 80% mortality in 13 days (Zhang et al. 2015). In addition, the Cotton bollworm Nuclear Polyhedrosis Virus (NPV) causes high mortality of locusts when viral DNA is mixed with nano-particles (Liu et al. 2016). Recent research has shown that heavy grazing promotes outbreaks of the Asiatic grasshopper *Oedaleus asiaticus* (Cease et al. 2012), which means that better management of grasslands could reduce outbreaks. In recent years, there has been the development and testing of new more precise monitoring and spraying methods, which are being incorporated into the preventive management program. A number of these advances have been in cooperation with international scientists and such cooperation will continue as part of ensuring China uses the most up to date techniques in locust and grasshopper management.

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